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ADAPTIVE GOVERNANCE OF SOCIAL-ECOLOGICAL SYSTEMS

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■ **Abstract** We explore the social dimension that enables adaptive ecosystem-based management. The review concentrates on experiences of adaptive governance of social-ecological systems during periods of abrupt change (crisis) and investigates social sources of renewal and reorganization. Such governance connects individuals, organizations, agencies, and institutions at multiple organizational levels. Key persons provide leadership, trust, vision, meaning, and they help transform management organizations toward a learning environment. Adaptive governance systems often self-organize as social networks with teams and actor groups that draw on various knowledge systems and experiences for the development of a common understanding and policies. The emergence of "bridging organizations" seem to lower the costs of collaboration and conflict resolution, and enabling legislation and governmental policies can support self-organization while framing creativity for adaptive comanagement efforts. A resilient social-ecological system may make use of crisis as an opportunity to transform into a more desired state.

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INTRODUCTION

The history of human use and abuse of ecosystems tells the story of adaptation to the changing conditions that we create. Often, the response has been to increase control over resources through domestication and simplification of landscapes and seascapes to increase production, avoid fluctuations, and reduce uncertainty (1, 2). This behavior has decreased temporal variability at the expense of increased spatial dependence on other areas on Earth. Human activities have become globally interconnected and intensified through new technology, capital markets, and systems of governance, with decisions in one place influencing people elsewhere. At the same time, the capacity of the environment, from local ecosystems to the biosphere, to sustain societal development seems to have been reduced over historical time (3, 4) and at increasing pace during the past century (5). This has lead to vulnerability in many places and regions with constrained options for human livelihoods and progress (6, 7). But has humanity adapted its capacity for learning and foresight to deal with this new and challenging situation?

Sometimes change in ecosystems and society is gradual or incremental. During periods of steady progress, things move forward in roughly continuous and predictable ways. At other times, change is abrupt, disorganizing, or turbulent. During such periods, experience tends to be incomplete for understanding, consequences of actions are ambiguous, and the future of system dynamics is often unclear and uncertain (8). Evidence points to a situation where periods of abrupt change are expected to increase in frequency, duration, and magnitude (9). At the same time, the capacity of ecosystems to remain within desired states in the face of abrupt change seems to have been reduced as a consequence of human actions (10). Vulnerable terrestrial and aquatic ecosystems may easily shift into undesired states in the sense of providing ecosystem services to society. The existence of such alternate regimes poses new fundamental challenges to environment and resource management (11).

Theories and approaches to environment and resource management have to a large extent focused on single issues or resources and been based on a steady-state view, interpreting change as gradual and incremental and disregarding interactions across scales. Such partial approaches are less useful in the current situation wherein the capacity of many ecosystems to generate resources and ecosystem services for societal development has become vulnerable to change and no longer can be taken for granted. Furthermore, it is now clear that patterns of production, consumption, and well-being arise not only from economic and social relations within regions but also depend on the capacity of other regions' ecosystems to sustain them (12, 13). A major challenge is to assure this capacity in the face of change (14).

Emerging theories and approaches point to the importance of assessing and actively managing resilience, i.e., the extent to which a system can absorb

recurrent natural and human perturbations and continue to regenerate without slowly degrading or even unexpectedly flipping into less desirable states (10, 15–17). Resilience in this context is defined as the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks (18). Science and policy for sustainability need to address the interplay between periods of gradual and abrupt change and their relations to resilience. There is also need to account for interactions across spatial and temporal scales to secure the capacity to reorganize in the face of change. It will require new forms of human behavior with a shift in perspective from the aspiration to control change in systems, assumed to be stable, to sustain and generate desirable pathways for societal development in the face of increased frequency of abrupt change (19).

The ecological basis for such an approach is developing and includes recognition of ecosystems as complex adaptive systems and the necessity to address uncertainty and surprise (20–22). It is moving from the conventional approach based on assessment of the maximum sustainable yield of individual species at a single broad scale to a more general focus on managing essential ecological processes that sustain the delivery of harvestable resources and ecosystem services at multiple scales (23–25). Significant roles of biological diversity in the dynamics and resilience of complex adaptive systems faced with change become part of the process (26–28) of such an ecosystem-based management approach (29).

Furthermore, the ecosystem-based approach recognizes the role of the human dimension in shaping ecosystem processes and dynamics (30, 31). Also, the human dimension reflects properties of complex adaptive systems, such as a diverse set of institutions and behaviors, local interactions between actors, and selective processes, that shape future social structures and dynamics (32–35).

Scholars have used concepts like coupled human-environment systems (36), ecosocial systems (37) and socioecological systems (38, 39) to illustrate the interplay between social and ecological systems, but treating the social or ecological dimension as a prefix may give it less weight during the analysis. Consequently, Berkes & Folke (40) started to use the term "social-ecological" system to emphasize the integrated concept of humans in nature and to stress that the delineation between social and ecological systems is artificial and arbitrary. Research suggests that social-ecological systems have powerful reciprocal feedbacks and act as complex adaptive systems (8, 31, 41–43).

It is important to clarify that implications of analyses of social-ecological systems generally differ from analyses of social or ecological systems alone (44, 45). Addressing only the social dimension of resource management without an understanding of resource and ecosystem dynamics will not be sufficient to guide society toward sustainable outcomes. For example, the mobilization of Belizian coastal fishermen into cooperatives, which was socially desirable and economically successful, led ultimately to excessive harvesting of stocks of lobster and conch (46). Similarly, focusing only on the ecological side as a basis for decision making for sustainability may lead to too narrow conclusions. For example, an observed shift in a lake from a desired to a less desired state may indicate that the lake has lost

resilience, but if there is capacity in the social system to respond to change and restore the lake the social-ecological system is still resilient (47, 48).

The capacity to adapt to and shape change is an important component of resilience in a social-ecological system (42). In a social-ecological system with high adaptability, the actors have the capacity to reorganize the system within desired states in response to changing conditions and disturbance events (18). Adaptive management (49) is often put forward as a more realistic and promising approach to deal with ecosystem complexity (50) than management for optimal use and control of resources (1, 44). Dietz et al. (51) used the concept of adaptive governance to expand the focus from adaptive management of ecosystems to address the broader social contexts that enable ecosystem-based management. By governance, we mean creating the conditions for ordered rule and collective action (52) or institutions of social coordination (53). Governance is the structures and processes by which people in societies make decisions and share power (54). Advocating an adaptive ecosystem approach, Boyle et al. (55) suggest a triad of activities, wherein governance is the process of resolving trade-offs and of providing a vision and direction for sustainability, management is the operationalization of this vision, and monitoring provides feedback and synthesizes the observations to a narrative of how the situation has emerged and might unfold in the future.

There has been substantial progress in understanding the social dimension of ecosystem management, including organizational and institutional flexibility for dealing with uncertainty and change (8, 40, 42, 51, 56–61) and social capital (62–64). Challenges for the social sciences have been raised in this context (65, 66). Social sources of resilience, such as social capital (including trust and social networks) and social memory (including experience for dealing with change) (67), are essential for the capacity of social-ecological systems to adapt to and shape change (68).

Here, we extend the framework of ecosystem-based management, as currently applied, to explore the social dimension in what we refer to as adaptive governance of social-ecological systems. We concentrate our review on experiences of governance in relation to complex adaptive ecosystems and in particular during periods when change is abrupt, disorganizing, or turbulent. This is the time when existing structures are most challenged, and the risk for a shift into undesired regimes is the highest. We are particularly interested in social sources that seem to be of significance in responding to and shaping change as well as building resilience for reorganization in social-ecological systems, both internally and in relation to external drivers. The focus is on local and regional governance of landscapes and seascapes.

In the first part of the review, we address the social responsiveness to ecosystem dynamics, in particular learning from the level of individuals through management practice and social networks to organizations. It is argued that adaptive governance is operationalized through adaptive comanagement systems and that the roles of social capital, focusing on networks, leadership, and trust, are emphasized in this context. The second section strives toward understanding social sources of resilience, in particular the interplay between crisis and mobilization of social memory for reorganization. The issues of transformation of social-ecological

systems toward adaptive governance as well as ecosystem and landscape management are investigated. The third section addresses the capacity of adaptive governance systems to cope with and make use of external perturbations and challenges in the broader social-ecological environment. We emphasize the role of bridging organizations that have the ability to strengthen social capital and the capacity for effective governance of multilevel organizations involved with ecosystem management. We conclude by presenting four essential features of adaptive governance of social-ecological systems.

SOCIAL CAPACITY FOR RESPONDING TO AND SHAPING ECOSYSTEM DYNAMICS

Management is about bringing together old knowledge, from diverse sources, into new perspectives for practice (58). Management of ecosystem resilience to sustain resources and ecosystem services requires the ability to observe and interpret essential processes and variables in ecosystem dynamics to develop the social capacity to respond to environmental feedback and change (23, 40, 69). Processes that generate learning, meaning, knowledge, and experience of ecosystem dynamics expressed in management practice are part of the social capacity of responding to environmental change.

Knowledge, Learning, and Practice

Much of contemporary science of natural resource management is focused on detailed single-species models, and policy recommendations are based on optimal sustainable use of these species without accounting for the role of ecosystem dynamics and regional patterns and processes (21). Managing for control and stability sets the system on a path to turbulent change (70). Therefore, the goal should be to seek not detailed knowledge of parts of the system but improved understanding of the dynamics of the whole system. Knowledge generation for understanding and managing periods of rapid change, the social sources of resilience required for reorganization following change, as well as strategies for dealing with true uncertainty and surprise in this context are still in their infancy (8, 71, 72).

Facing complex adaptive systems and periods of rapid change gives the scientist a new role in decision making from being an objective and detached specialist expected to deliver knowledge to managers to becoming one of several actors in the learning and knowledge generation process (31, 73, 74). Other actors include local groups with experience in resource and ecosystem management (75, 76). Efforts are taking place to mobilize, make use of, and combine different knowledge systems and learning environments to enhance the capacity for dealing with complex adaptive systems and uncertainty (44). It comes as no surprise that knowledge of ecosystem dynamics and associated management practices exists among people of communities that, on a daily basis and over long periods of time, interact for

their benefit and livelihood with ecosystems (77, 78). The way such knowledge is being organized and culturally embedded, its relationship to institutionalized, professional science, and its role in catalyzing new ways of managing environmental resources have all become important subjects (79–85).

There is a growing literature on the potential in combining local knowledge systems with scientific knowledge to cope with change in resource and ecosystem management, including understanding climate change (86) and managing fisheries, biodiversity, and landscape dynamics (87–90). For example, in the Solomon Islands, indigenous knowledge, practice, and sea tenure systems were used in combination with scientific knowledge to establish marine protected areas for bumphead parrotfish conservation (91). A self-governing community in Ecuador changed their unsustainable forest management practice by incorporating scientific knowledge about the interplay between freshwater and forest dynamics into their traditional knowledge system and thereby curtailed destruction of their moist forest commons (92). It has been argued that such self-organized local responses for active adaptation to environmental change have emerged among communities and societies that have survived over long periods of time (75).

Berkes & Folke (93) identify management practices that cope with periods of rapid environmental change in what has been referred to as the "back-loop" of social-ecological system development (8, 42). They divide them into practices that evoke change, that survive change, and that nurture sources for reorganization following change (93). McCay (94) refers to the economics of flexibility where diversification is the primary strategy. Robust, adaptive strategies of social-ecological systems accept uncertainty and change (22). They take advantage of rapid change and surprise and turn them into opportunities for development. Many local communities have long recognized the necessity of coexisting with gradual and rapid change. There are groups with associated institutions that have accumulated a knowledge base of how to relate to and respond to environmental feedback, which allows the disturbance to enter at smaller scales instead of accumulating to larger scales, thereby precluding large-scale collapse (95, 96). Such management practices seem to have developed as a result of experience with change and crisis, realizing that not all possible outcomes can be anticipated, planned, or predicted (40).

Crisis, perceived or real, seems to trigger learning and knowledge generation (58) and opens up space for new management trajectories of resources and ecosystems. For example, Olsson & Folke (97) described how threats of acidification, overfishing, and disease successively initiated learning and generated ecological knowledge among local groups in the Lake Racken catchment in western Sweden. The ecological knowledge system covers scales from physiology of the resource to integrative knowledge of catchment processes. Knowledge acquisition of complex adaptive ecosystems is an ongoing, dynamic learning process, and such knowledge often emerges over decades with peoples' institutions and organizations, as illustrated for frontier colonist farmers in the Brazilian Amazon (98). The ecosystem-based management of the Lake Racken catchment, in which the

ecological knowledge system is embedded, emerged in about a decade, and people now interact through social networks across local to national organizational and institutional levels.

Adaptive Management and Organizational Learning

Because the self-organizing properties of complex ecosystems and associated management systems seem to cause uncertainty to grow over time, understanding should be continuously updated and adjusted, and each management action viewed as an opportunity to further learn how to adapt to changing circumstances (22). This is the foundation for active adaptive management wherein policies become hypotheses, and management actions become the experiments to test those hypotheses (99). Walters (100) in his review of adaptive management of riparian ecosystems argues that a reason for failure lies in management stakeholders showing deplorable self-interest, seeing adaptive-policy development as a threat to existing research programs and management regimes, rather than as an opportunity for improvement. This is why it is important to address the social dimension and contexts for adaptive governance in relation to ecosystem management, including processes of participation, collective action, and learning.

Developing the capacity of individuals to learn effectively from their experiences is an important part of building knowledge and skills into organizations and institutions to permit good adaptive management (101). Learning that helps develop adaptive expertise (an individual's ability to deal flexibly with new situations) and processes of sense making (102) are essential features in governance of complex social-ecological systems, and these skills prepare managers for uncertainty and surprise. Sense making implies taking interpretations seriously, inventing and reinventing a meaningful order and then acting upon it (45). Learning for ecosystem management is often considered to be a social process referred to as "social learning" (56, 103). Authors have also used the concept "institutional learning." For example, Ostrom (61) stresses that although theory and evidence play a key role in increasing the probability of selecting rules for resource management, leading to better as contrasted to worse outcomes, they cannot eliminate the need to view all policies as ongoing learning experiments that need to be monitored, evaluated, and adapted over time.

The social context of learning is further stressed in the literature on organizational learning (e.g., Reference 58). The confrontation of underlying assumptions, norms, and objectives and the changes in mental models and meaning were referred to as double-loop learning by Argyris (104) and applied in relation to ecosystem management by, e.g., Blann et al. (105). In recent organizational literature, resilience (interpreted as the capacity for innovation and renewal) has been proposed as a key feature that allows industries to survive turbulent times and reorganize (106). Whiteman et al. (107) argue that business theory and practice need to move beyond organizational resilience and embrace ecosystem resilience in management goals.

Organizational learning is not limited to formal organizations but also takes place in loosely defined organizations (108). For example, Fazey et al. (101) describe how managers of marsh areas in Australia combined their external experiences for a collective interpretation of ecosystem dynamics, and Olsson et al. (109) illustrate how knowledge for ecosystem management in southern Sweden, generated through local innovation, learning, and practice, as well as through external experiences and contacts, is collectively mobilized in overlapping subsets of the social network and applied in landscape management. Hence, social systems are structured not only by rules, positions, and resources but also by meaning and by the entire network of communicating individuals and organizations at different levels of interaction, representing the social system involved in governance of ecosystems (58, 110). A clear and convincing vision, comprehensive stories and meaning, and good social links and trust with fellow stakeholders may mobilize several interest groups at several levels and start a self-organizing process of learning and social capital generation for management of complex adaptive ecosystems (111).

Governance and Adaptive Comanagement

The self-organizing process may emerge into systems of adaptive comanagement (109, 112). "Adaptive comanagement" systems are flexible community-based systems of resource management tailored to specific places and situations, and they are supported by and work with various organizations at different levels. The flexible structure allows for learning and ways to respond to and shape change. Folke et al. (113) define adaptive comanagement as a process by which institutional arrangements and ecological knowledge are tested and revised in a dynamic, ongoing, self-organized process of learning by doing. Adaptive comanagement combines the dynamic learning characteristic of adaptive management (e.g., Reference 49) with the linkage characteristic of cooperative management (e.g., References 114 and 115) and also with collaborative management (e.g., Reference 116). Comanagement is concerned with the problem-solving process involved in sharing of management power across organizational levels (117). Authors have identified social conditions that need to be fulfilled in comanagement systems (e.g., References 118 and 119).

Adaptive comanagement relies on the collaboration of a diverse set of stakeholders, operating at different levels, often through networks from local users to municipalities, to regional and national organizations, and also to international bodies. The sharing of management power and responsibility may involve multiple institutional linkages among user groups or communities, government agencies, and nongovernmental organizations (NGOs). In addition, adaptive comanagement extends adaptive management into the social domain and is a way to operationalize adaptive governance. Although adaptive management focuses on understanding ecosystem dynamics and feeding ecological knowledge into management organizations, adaptive governance conveys multi-objective reality when handling

conflicts among diverse stakeholders and, at the same time, adapts this social problem to resolve issues concerning dynamic ecosystems (51). The term "governance" has recently become a catchword for various alternatives to conventional top-down government control, including collaboration, partnerships, and networks (120). Issues of legitimacy and accountability are often stressed in the literature on governance (121, 122), and good governance of ecosystems has been interpreted as solving the trilemma characterized by tensions between effectiveness, participation, and legitimacy (123).

Governance emerges from many actors in the state-society complex and can be institutionalized or expressed through subtle norms of interactions or even more indirectly through influencing agendas and shaping contexts in which actors contest decisions and access resources (54). In a review of the recent governance literature (L. Martin, unpublished paper), Martin found a new appreciation of loosely structured governance entities that spontaneously emerge or self-organize, often in response to rigid governmental structures. Lee (53) refers to such adaptive systems of governance as the new governance and defines it as a polycentric form of social coordination in which actions are coordinated voluntarily by individuals and organizations with self-organizing and self-enforcing capabilities.

Adaptive governance of ecosystems generally involves polycentric institutional arrangements, which are nested quasi-autonomous decision-making units operating at multiple scales (124, 125). They involve local, as well as higher, organizational levels and aim at finding a balance between decentralized and centralized control (126). The vertical links of such arrangements may boost adaptive governance, for instance when local and national institutions gain strength from being nested in regional and global institutions. Such links can also stifle adaptive governance, as in cases where national land-use regulations contradict or undermine informal local systems of land tenure (127) and limit practitioners' abilities to exploit an interorganizational network's collaborative capacity (128). Institutional interaction across organizational levels can increase the diversity of response options and can deal more appropriately with uncertainty and change (61). Furthermore, such polycentric arrangements may be of significance in responding to ecosystem dynamics at different scales. The ability to use institutions effectively, at organizational levels appropriate to the ecological scale, has been referred to as scale-matching (56) or institutional fit (84, 129).

Adaptive Governance and Social Capital

Adaptive governance involves devolution of management rights and power sharing that promotes participation. However, devolution of management rights does not automatically result in adaptive comanagement. Adaptive comanagement requires social networks (in the sense of Reference 130). For example, the devolution of management rights in1994 in Sweden to a fishing association resulted in increased local control over the management of fish and crayfish in inland freshwater lakes and streams (97). It did not initially involve efforts to develop partnerships among

actors at local to state levels. However, in 1998 the Swedish Environmental Protection Agency and the National Board of Fisheries initiated a joint project between Norway and Sweden to implement an action program for conserving the noble crayfish (131). It involves collaboration between county administration boards, municipalities, rural economic and agricultural associations, local fishing associations, the Swedish Environmental Protection Agency, and the National Board of Fisheries of both countries. It is funded by the European Commissions Interreg program, three Norwegian and two Swedish county administrations boards, and several Norwegian municipalities. The action program for the noble crayfish illustrates an alternative governance form within a polycentric institutional structure, which assumed a new role for government and governmental agencies and stimulated the emergence of adaptive governance. External resources and actors can play an important role, interacting with internal and local ones, in creating civic arenas or forums as well as social and political spaces for deliberation (94). Schneider et al. (132) state that formal lines of authority are blurred in these self-organized network-based governance systems in which diverse policy actors are knitted together to focus on common problems, but these multilevel networks can stimulate collaboration, build trust, provide information, and encourage the development of common perspectives on policy issues. Such networks represent informal governance systems across organizational levels with an interest in influencing and implementing policies in a given resource area. They have been referred to as policy communities (133) or epistemic communities (134).

In times of rapid change informal social networks can provide arenas for novelty and innovation and enhance flexibility, all of which tend to be stifled in bureaucracies (99). However, these network structures do not replace the accountability of existing hierarchical bureaucracies but operate within and complement them (135). As observed by Steel & Weber (136), too much decentralization may counteract its purpose and miss the opportunity of collective action that involves several organizational levels.

Networks of collaboration may emerge from different actors and levels, including local as well as governmental initiatives. Schusler et al. (137) describe a successful attempt by a New York State agency to encourage comanagement through a deliberative process. Aided by researchers, the agency initiated collaboration and catalyzed social learning. The stakeholders were invited to a conference and learned about system dynamics of the basin, about the concerns of other participants, and as much as half of them experienced value formation and altered their own concerns related to natural resource management in the area. Formal collaboration initiated by authorities can be supported by legislation and institutional interaction, as the polycentric fishing institutions in Sweden, or be nonstatutory arrangements with the purpose of collaborative learning and conflict resolution, as the example by Schusler illustrates. Berkes (138) distinguishes between real comanagement, with shared management authority, and multistakeholder bodies that are often used by government agencies to increase legitimacy and manage conflicts without devolution of power.

Governing complex adaptive ecosystems requires adaptive managers supported by flexible organizations (58); problem-oriented organization or adhocracy organizations (139) have been suggested by Danter et al. (59) and observed by Imperial (128) as significant in this context. In Kristianstad, Sweden, the loosely connected horizontal and vertical networks are based on voluntary participation, and key persons are mobilized to form ad hoc project organizations when pressing issues arise (140). These collaboration networks can provide an arena where social capital is enhanced and where concerns are reformulated to generate innovation and nurture renewal in times of reorganization. Informal collaboration dominates at the local level but may also span the regional and global levels. For instance, UNESCO Man and Biosphere reserves are often governed by an informal ad hoc assembly of concerned individuals and NGOs with no legal power but ability to influence the policy-making process (55).

Collaboration in governance networks requires leadership. Here we focus on leadership in the direction of adaptive governance of social-ecological systems. Crises open up arenas for new leadership with various objectives (99). In a review of the empirical literature on watershed partnership by Leach & Pelkey (141), effective leadership and management was the second most frequent factor for successful partnership after adequate funding. Leadership is essential in shaping change and reorganization by providing innovation in order to achieve the flexibility needed to deal with ecosystem dynamics. This is addressed by Shannon (142) in her work on the role of policy entrepreneurs in forest management and by Kuhnert (143) and Ostrom (144) on public entrepreneurs in relation to irrigation- and groundwater basin management. Furthermore, entrepreneurial leaders have proven their significance in the development of international institutions by functioning as agenda setters, popularizing issues at stake, devising policy options to overcome bargaining impediments, brokering deals, and lining up support for salient options (145). Leaders can provide key functions for adaptive governance, such as building trust, making sense, managing conflict, linking actors, initiating partnership among actor groups, compiling and generating knowledge, and mobilizing broad support for change. Key individuals also develop and communicate visions of ecosystem management that frame self-organizing processes (58). These individuals often have the ability to manage existing knowledge within social networks for ecosystem management and further develop those networks. Lack of leaders can lead to inertia in social-ecological systems (111).

Trust makes social life predictable, it creates a sense of community, and it makes it easier for people to work together (146). Trust can be said to be the basis of all social institutions and is also integral to the idea of social influence, as it is easier to influence or persuade someone who is trusting (147, 148). Building trust and the growth of social network are closely related to investments in social capital. Pretty & Ward (149) refer to social capital as relations of trust, reciprocity, common rules, norms, sanctions, and connectedness in institutions. Several authors have regarded social capital as the glue for adaptive capacity and collaboration (63, 109, 149–151), whereas others have contested its empirically explanatory power

(152, 153). Social capital is built by investing in social relationships, and the networks that emerge can either focus on horizontal or vertical collaboration (111). Both dimensions seem to be necessary for transforming ecosystem management to more adaptive governance (58). Wondolleck & Yaffee (118) provide several examples of how public managers have invested in building trust and collaboration to meet their objectives in natural resource management. Stakeholder networks have emerged in some of the U.S. National Estuary Program areas (154). These areas have been found to span more levels of government, integrate more experts into policy discussions, build trust, reduce the level of conflict among key persons from different stakeholder groups, and as a result, increase the legitimacy of the program (132).

We emphasize that, to emerge and be effective, self-organized governance systems for ecosystem management require a civic society with a certain level of social capital (53, 149), and the governance system must continuously learn and generate experience about ecosystem dynamics. Social capital increases the flexibility of management organizations and institutions, but the social features and processes underlying reorganization after disturbance are not well understood. In the next section, we focus on social sources of resilience that make adaptive governance of social-ecological systems possible. We are particularly interested in social sources of resilience that can be mobilized to adapt to and shape periods of rapid and turbulent change as well as contribute to the reorganization of social-ecological systems into desired states.

SOCIAL SOURCES OF RESILIENCE FOR ADAPTABILITY AND TRANSFORMATION

Systems with high adaptive capacity are able to reconfigure themselves when subject to change without significant declines in crucial functions of the social-ecological system. Gunderson & Holling (8) argue that addressing how people respond to periods of change and how society reorganizes following change are the most neglected and the least understood aspects in resource management and science. Synthesizing several case studies, Folke et al. (68) identified and expanded on the following four critical factors that interact across temporal and spatial scales and that seem to be required for dealing with social-ecological dynamics during periods of rapid change and reorganization:

- Learning to live with change and uncertainty
- Combining different types of knowledge for learning
- Creating opportunity for self-organization toward social-ecological resilience
- Nurturing sources of resilience for renewal and reorganization

The first three factors have been dealt with above. Here, we focus on nurturing sources of resilience. The functional role of biological diversity as a source of

resilience in ecosystem renewal and reorganization is a growing area of research reviewed elsewhere (e.g., References 10 and 28). Here, we are concerned with the social sources in adaptive governance of social-ecological systems that help cope with and adapt to change and facilitate reorganization and innovation following disturbance and crisis.

Social Memory, Teams, and Actor Groups as Sources of Resilience

Resilience of social-ecological systems in the face of uncertainty and surprise is about promoting the capacity to expect the unexpected and absorb it (72). As suggested by Low et al. (155) diversity and redundancy of institutions and their overlapping functions across organizational levels may play a central role in absorbing disturbance and in spreading risks. Hence, it is an important challenge to overcome common perceptions of inefficiencies associated with redundancy, namely fragmentation and duplication of authority, policy inconsistencies, and high transaction costs (126). Accumulating experience through collective learning, mobilized during periods of rapid change as discussed above, is important in this context (56, 93). A collective memory of experiences with resource and ecosystem management provides context for social responses and helps the social-ecological system prepare for change. If experience embedded in institutions and organizations provides a context for the modification of management policy and rules, people can act adaptively in the face of surprise. They can navigate the turbulent phase and perform through diversification and redundancy rather than simplification (61, 155).

A crucial challenge for adaptive governance during periods of rapid change seems to be the mobilization of social memory. "Social memory" has been defined as the arena in which captured experience with change and successful adaptations, embedded in a deeper level of values, is actualized through community debate and decision-making processes into appropriate strategies for dealing with ongoing change (67). Social memory is important for linking past experiences with present and future policies. It is a part of the cultural capital of human society (156). A subset of social memory is the accumulation of a diversity of experiences concerning management practices and rules in use at the collective level. It draws on experience but allows for novelty, innovation, and experimentation within the framework of accumulated experience (e.g., Reference 140), referred to as framed creativity (68).

Social memory seems to play an important role in the adaptive comanagement process when key persons draw on social memory of several scales in reorganization following change. Social networks can be key mechanisms for drawing on social memory at critical times and enhance information flow and collaboration across scales. The social memory of past changes in ecosystems, and responses to these, can be mobilized and fed into processes whereby structures of governance of ecosystem are decided, management practices worked out, and conflicts resolved. This requires leadership at various organizational levels (110, 157).

Different agents/actors or team/actor groups seem to play significant roles, as part of social memory, in mobilizing the social network to deal with change and unexpected events and to reorganize accordingly. Guimerà et al. (158) find that team self-assembly mechanisms determine the structure of collaboration networks and team performance. They suggest that team size, the fraction of newcomers, and the tendency of incumbents to repeat previous collaboration are of significance. Holling & Chambers (159) identified in their workshops on adaptive management a set of characters that emerges in the process and that take on different roles from leadership to those who oppose and criticize. Gladwell (160) in his book on tipping points stresses the social roles of mavens (altruistic individuals, with social skills, who serve as information brokers, sharing and trading what they know) and connectors (individuals who know lots of people not only by numbers but the kind of people they know and in particular the diversity of acquaintances). They are the strength of the weak ties and enhance the information base of their social network. Mavens are data banks and provide the message. Connectors are social glue and spread the message, and then there are salesmen, individuals with the social skills to persuade people unconvinced of what they are hearing. All interact to create rapid and large change (160).

Many patterns of adaptive comanagement can be understood by personal traits, and these traits combined with the roles of teams or actor groups are important factors for building adaptive capacity and provide a source of social resilience in social-ecological systems. Bebbington (161) identified brokers with different backgrounds, including a priest, university professor, European volunteers, and funding agencies that came from outside and played key roles in sustainable agriculture intensification in the Andes. They brought in new ideas, but more importantly they brought in networks of contacts that helped the members of the local communities gain access to nonlocal institutions and resources, including access to NGOs with technical assistance and financial resources, sources of technology, donors, and alternative trading networks. Tompkins et al. (162) show how expanding and linking networks of dependence and exchange helps facilitate integrated and inclusive coastal management in Trinidad and Tobago. Such networks spread across national and international boundaries in ways that would have been hard for the locals to do on their own.

Other social roles of key individuals operating in teams or actor groups in adaptive comanagement systems include knowledge carriers, knowledge generators, stewards, leaders, and people who make sense of available information (109). Folke et al. (68), using several case studies, also identified the following actor groups: knowledge retainers, interpreters, facilitators, visionaries, inspirers, innovators, experimenters, followers, and reinforcers. Social capital focuses on relationships among such groups, i.e., the bridging and bonding links between people in social networks (163, 164). Applied to adaptive governance, these relationships must be fed with relevant knowledge on ecosystem dynamics. This is related to the capacity of teams to process information, to make sense of scientific data and connect it to an empirical context, to mobilize the social memory of

experiences from past changes and responses, and to facilitate adaptive and innovative responses.

Social roles of actor groups are all important components of social networks and essential for creating the conditions that we argue are necessary for adaptive governance of ecosystem dynamics during periods of rapid change and reorganization. Linking different actors groups in networks and creating opportunities for new interactions are important for dealing with uncertainty and change and critical factors for learning and nurturing integrated adaptive responses to change (165). We hypothesize that the combination of social roles of agent/actor and team/actor groups as part of social memory as well as their diversity, overlapping functions, and redundancy provide resilience for reorganization, allow for novelty, and thereby enhance adaptive capacity in the face of disturbance and crisis (68). But their combination may also cause barriers, collision, and erosion of social capital and social memory, as may be the case when different cultural value systems, worldviews, and discrepancies in conceptualization are brought together and interact (e.g., Reference 166) or when the cultural dynamics created by the policies of those in power during earlier periods may inhibit development of the ability to respond to disturbance and surprise (99). In this sense, the underlying worldview of resource management (167) may impose a grid on social memory for managing ecosystem dynamics (1), and opinion shifts may be inhibited by credible authorities, who neglect the problem, or by competition for attention to other issues and problems that take place simultaneously (111).

However, key individuals with strong leadership may catalyze opinion shifts (111, 160), and creative teams and actor groups may emerge into a large connected community of practitioners who prepare a social-ecological system for change (105, 158) and transform it into a new state as discussed below. Such fundamental change in social-ecological systems can occur rapidly (111).

Transforming Governance for Social-Ecological Sustainability

Surprise and crisis seem to create space for reorganization, renewal, and novelty as well as provide opportunities for new ways of social self-organization for resilience (8). The crises may be caused by, for example, external markets and tourism pressure, floods and flood management, shifts in property rights, threats of acidification, resource failures, rigid paradigms of resource management, and new legislation or governmental policies that do not take into account local contexts (42). A social-ecological system with low levels of social memory and social capital is vulnerable to such changes and may as a consequence deteriorate into undesired states.

In contrast, crisis may trigger mobilization of social capital and social memory and may result in new forms of governance systems with the ability to manage dynamic ecosystems and landscapes. This has been referred to as building social capacity for resilience in social-ecological systems (68), and it requires inducing

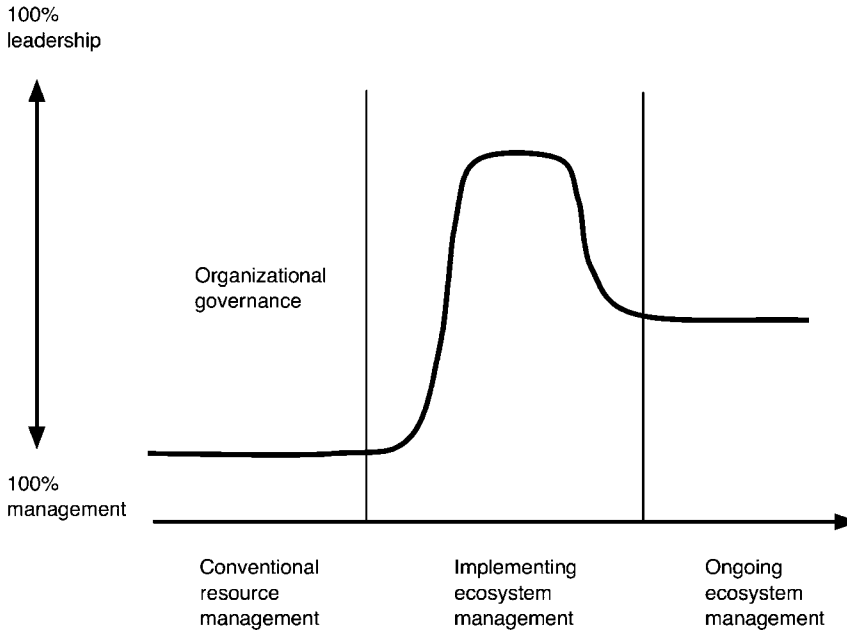

Figure 1 The role of leadership in transforming an organization toward ecosystem management and sustaining it [modified from Danter et al. (59)].

change in social structures (58). For instance, in a study of the U.S. Fish and Wildlife Service, Danter et al. (59) highlight the need for organizational change as a component of ecosystem management and put forward the role of leadership in actively initiating change within organizations (Figure 1). Visionary leaders fabricate new and vital meanings, overcome contradictions, create new synthesis, and forge new alliances between knowledge and action (58). Leadership that can engage and change the opinions and values of a critical mass of people to create an epidemic movement toward an idea has been investigated by Scheffer et al. (111) and is referred to as tipping-point leadership (168). Kingdon (169) stresses the importance of timing for initiating change and suggests that policy windows open either when decision makers perceive a problem as pressing and seek a policy (problem-driven window) or when they adopt a theme for their administration and look for problems that may justify change and proposals that are along the theme (politically driven window). A policy entrepreneur in this context is a person who connects political momentum to problem perception and a policy proposal. Grindle & Thomas (170) have also studied the role of such key individuals in shaping and influencing policy and institutional change with a focus on developing countries. Key individuals assess and identify a range of opportunities for change, a process referred to as creating policy space. Single individuals have also been found to play key functions in managing boundaries between different organizations involved in

science and policy and also in the context of learning, knowledge generation, and social responses for dealing with global environmental risks (103, 171), including the social amplification of risk (172).

In the literature on resilience, adaptability is the capacity of actors in a social-ecological system to manage resilience in the face of uncertainty and surprise. It implies remaining and developing within the current attractor of the social-ecological system. In contrast, transformability is the capacity to create a fundamentally new system when ecological, economic, or social (including political) conditions make the existing system untenable. Transformability means creating and defining a new attractor that directs the development of the social-ecological system by introducing new components and ways of making a living, thereby changing the state variables, and often the scales of key cycles, that define the system (18).

Transformations toward alternative forms of governance have been addressed by Kettl (135), Kuks & Bressers (173) and Agrawal (174). In a recent paper (109), we analyzed the emergence of a governance system for adaptive comanagement of the wetland landscape of Kristianstad in southern Sweden, a process whereby unconnected management by several actors in the landscape was mobilized, renewed, and moved into a new configuration of ecosystem management within about a decade. The self-organizing process was triggered by the perceived threats to the area's cultural and ecological values among people of various local steward associations and local government. A key individual provided visionary leadership in directing change and transforming governance. The transformation involved four phases: (*a*) preparing the system for change, (*b*) the opening of an opportunity, (*c*) navigating the transition, and (*d*) charting a new direction for management while building resilience of the new governance regime (Figure 2). Trust-building dialogues, mobilization of social networks with actors and teams across scales, coordination of ongoing activities, sense making, collaborative learning, and creating public awareness were part of the process. A comprehensive framework with a shared vision and goals that presented conservation as development and turned problems into opportunities was developed and contributed to a shift in values and meaning of the wetland landscape among key actors. The shift was facilitated through broader scale crises, such as seal deaths and toxic algal blooms in the North Sea, which caused environmental issues to become top priority on the national political level, at the time of a search for a new identity at the municipality level. Hence, a window of opportunity at the political level opened, which made it possible to tip and transform the governance system into a trajectory of adaptive comanagement of the landscape with extensive social networks of practitioners engaged in multilevel governance. The transformation took place within the existing institutional framework (140). As observed by McCay (94), changing perceptions of the environment can change human behavior on a fairly large scale without involving the social dynamics and political behavior involved in making and changing rules.

Transformational leadership includes recognizing opportunities, identifying and transforming constraints and barriers, such as conflicts of interests, values,

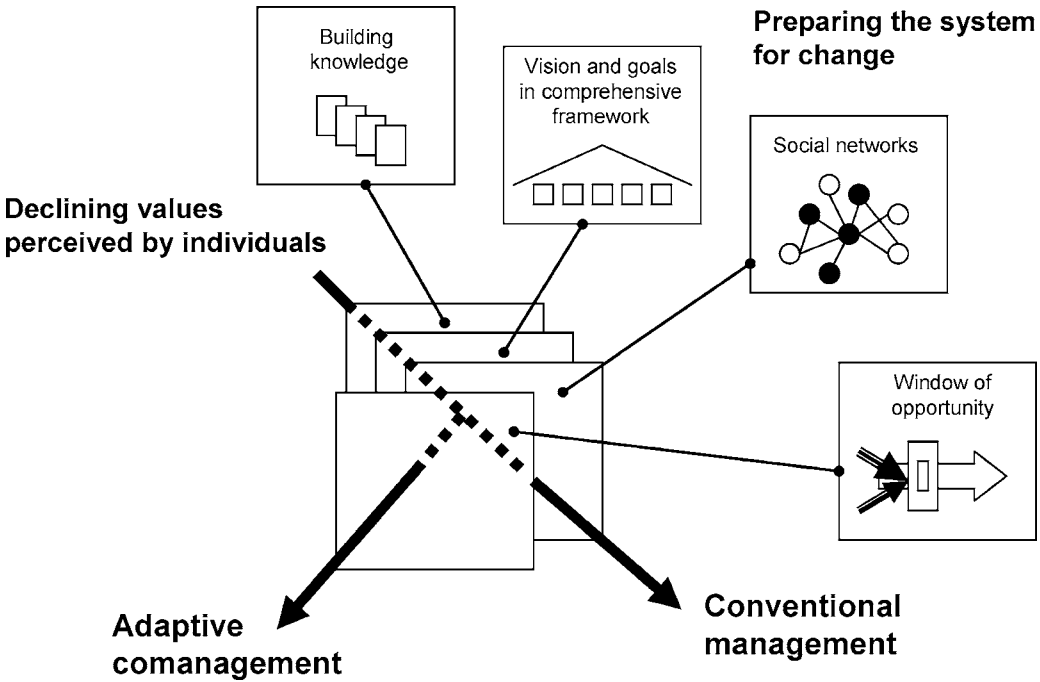

Figure 2 Transformation toward adaptive comanagement of the wetland landscape in southern Sweden. The transformation was orchestrated by leaders providing vision and meaning, learning and knowledge generation, and gluing and expanding social networks, thereby preparing the social-ecological system for change when the opportunity opened [reprinted with permission from Olsson et al. (109)].

and opinions (175). This is critical for reducing the resilience of undesired trajectories and building up a momentum for moving into new trajectories (58). Currently efforts in the wetland landscape of Kristianstad are directed toward strengthening the resilience of the new governance system in the performance of ecosystem management. Olsson et al. (109) identified 30 different strategies for increasing the capacity for dealing with uncertainty and change and divided these strategies into developing motivation and values for ecosystem management, directing the local context through adaptive comanagement, and navigating the larger environment. The new governance system strives to combine vision, direction, learning, and management and has been instrumental in orchestrating the area to become the first Man and the Biosphere Reserve in Sweden.

Successful social transformations toward adaptive governance for ecosystem management seem to be preceded by the emergence of informal networks, orchestrated by key individuals, that help facilitate information flows, identify knowledge gaps, and create nodes of expertise of significance for ecosystem management that can be drawn upon at critical times. These networks place emphasis on political independence, out of the fray of regulation and implementation, places where formal networks and many planning processes fail (50). Gunderson et al. (99) have emphasized the role of such shadow networks as incubators of new approaches for governing social-ecological systems. Because members of these networks are not always under scrutiny or obligations of their agencies or constituencies, most likely they are freer to develop alternative policies, dare to learn from each other, and think creatively about the resolution of resource problems. But, even if the new adaptive governance system is performing in a resilient manner through adaptive comanagement of ecosystems and landscapes it may be challenged and fragile during changes in external drivers.

ADAPTIVE GOVERNANCE IN RELATION TO THE BROADER ENVIRONMENT

Lots of efforts may go in to supporting the emergence of adaptive governance for management of ecosystems, and such governance may perform quite successfully during periods of gradual change. But rapid change may challenge the whole governance system. In the Kristianstad example, a change in European Union agricultural subsidies of cattle grazing or a rapid increase in climate-induced flooding may perturb the system and cause irreversible change. Therefore, key stewards actively develop strategies that prepare for uncertainty and surprise. They navigate the larger environment of social, economic, and ecological drivers to reduce vulnerability and thereby enhance their ability to cope with change as resource development continues along desired trajectories.

Vulnerability research emphasizes the importance of addressing both the role of external forces and rapid change in reshaping social-ecological systems as well as the different capacities of agents/actors in the system to respond to change on the basis of their access to social and biophysical capital (36). In their review on

causes behind land-use change, Lambin et al. (176) argue that land-use change can be understood using the concepts of complex adaptive systems and transitions. They illustrate that synergies between resource scarcity leading to an increase in the pressure of production on resources, changing opportunities created by markets, outside policy intervention, loss of adaptive capacity, and changes in social organization and attitudes are essential drivers that challenge governance systems in tropical regions. The strength of marine tenure institutions in Papua New Guinea and Indonesia seems to be undermined by connectivity to larger markets. Immigration, dependence on fishing, and conflicts also impact marine tenure systems (177). Differences in land tenure, agricultural policy, and market conditions are more significant drivers of long-term changes in semiarid African savannas than are agro-pastoral population growth, cattle numbers, or small-holder land use (178). Increasing vulnerability places a region on a trajectory of greater risk to the panoply of stresses and shocks that occur over time. Catastrophes, i.e., undesirable sudden changes in social-ecological systems, are due to a combination of the magnitude of external forces and the internal resilience of the system. As resilience declines, it takes a progressively smaller external event to cause a catastrophe. The process is a cumulative one in which sequences of shocks and stresses punctuate the trends, and the inability to replenish coping resources propels a region and its people to increasing criticality (6, 7, 179).

Hence, adaptive governance of social-ecological resilience also requires capacity to deal with the broader environment and preparation for uncertainty and surprise (180). A growing literature on polycentric institutions (124, 125, 181) demonstrates that flexible coping with external drivers and rapid change is enhanced by systems of governance that exist at multiple levels with some degree of autonomy, complemented by modest overlaps in authority and capability (155). Such flexible institutional arrangements have been judged as inefficient because they look messy and are nonhierarchical in structure, but they help provide a repertoire of general design principles that can be drawn on by resource users at multiple levels to aid in the crafting of new institutions that cope with changing situations (182, 183).

A lot of attention is given to multilevel governance and cross-scale interactions in relation to social-ecological systems and adaptive comanagement (e.g., References 41, 127, 129, 138, 184–186). The real challenge is dealing with systems that are not only cross-scale but also dynamic, whereby the nature of cross-scale influences in the linked social-ecological system changes over time, creating fundamental problems for division of responsibility between centralized and decentralized agents (187). Gunderson & Holling (8) use the concept "panarchy" as a heuristic model to conceptualize complex interactions, emphasizing the interplay between periods of gradual and rapid change within and between scales and between novelty and memory, and scholars have used such aspects to address change in complex adaptive social-ecological systems (e.g., References 188 and 189).

An important factor in this context is organizations in adaptive comanagement that emerge to bridge local actors and communities with other scales of

organizations. Such bridging organizations can serve as filters for external drivers (190) and also provide opportunities by bringing in resources, knowledge, and other incentives for ecosystem management. Westley (58) used the term "bridging" for interorganizational collaboration. In Kristianstad, southern Sweden, a bridging organization, the Ecomuseum Kristianstad Vattenrike, emerged as a local response to the perceived crisis in wetland landscape management. The Ecomuseum provides an arena for building trust, sense making, learning, vertical and/or horizontal collaboration, and conflict resolution. The bridging organization encompasses the function of a boundary organization (171, 191) by communicating, translating, and mediating scientific knowledge to make it relevant to policy and action. The organization also uses its network of stakeholders to mobilize knowledge and social memory in turbulent times, which in turn help deal with uncertainty and shape change (68).

NGOs may act as bridging organizations in, for example, community-based ecosystem management in tropical regions, and scientists may serve as visionary leaders in the process (e.g., Reference 81). The Millennium Ecosystem Assessment (http://www.maweb.org) provides several local examples of how bridging organizations perform essential functions in crafting effective responses, often without changing formal institutions (192). These include the bottom-up initiative in Sweden, a top-down initiative in the Philippines, and external initiatives in Indonesia and Chile. About 12 million people live around the Laguna Lake in the Philippines. The governance was compartmentalized and nonparticipatory before the authorities formed 33 River Rehabilitation Councils (RRCs), which included several stakeholders. The RRCs can be regarded as bridging organizations that are able to address social as well as ecological drivers and make comprehensive and effective responses to declining trends. The scientific community played an important role in the formation of RRCs (193). Development agencies and research institutes, such as the Alternatives to Slash and Burn (ASB) program of International Centre for Research in Agroforestry, can also act as catalyzer and perform functions similar to bridging organizations. In Indonesia, the ASB facilitated a tenure reform by investing several years in dialogue and consensus building with NGOs, local government offices, and the Krui community. Eventually the ASB managed to convince the authorities of the high social benefits from community agroforestry (194). In northern Chile, a small research center without formal political or economic power managed to provide an arena with an advisory committee, for indigenous communities, large mining companies, tourist operators, and local government officials. Access to information and the unique opportunity to interact because of a complex and pressing issue attracted these participants. A history of distrust was broken when, for the first time, they sat down together to discuss ecosystem management and local development. Capacity building was reinforced through scenario workshops undertaken in late 2004, as part of The Millennium Ecosystem Assessment (195).

Bridging organizations thrive under open institutions (196), which provide flexibility and space for dealing with the ambiguity of multiple objectives. These are important in strengthening the adaptive capacity of local actors. By reducing the

(nonmonetary) transaction costs of collaboration, bridging organizations can be described as providing social incentives to stakeholders to invest in building trust, identification of common interests, and resolving conflict (140). The facilitation, leadership, and social incentives for collaboration provided by bridging organizations or key persons in the community appear to be essential for building the capacity to adapt to change (118).

In a similar vein, McCay (94) states that emergence of viable governance institutions may depend on the creation of large multistakeholder organizations or encompassing organizations. She refers to a coordinating unit that was created in Ecuador (using a model tried out in Mexico) and that represented local communities, timber companies, government agencies, environmental NGOs, and foreign assistance groups. It became a forum for discussion and debate on sustainable forestry issues, and a civic arena for bargaining and making compromises and trade-offs, as well as communication. The local communities were able to improve the terms of trade with the timber companies because they could exchange information on deals offered and cooperate in demanding better prices. The timber companies also benefited by getting the communities to agree on a workable policy for sales of timber land.

CONCLUSION

In recent years cooperative and collaborative efforts and participatory approaches have become increasingly popular in ecosystem management and governmental policy. Stakeholder meetings, engaging different actors in workshop settings, have been part of the process. There has been a tendency, however, for the natural scientists to do the science first or governmental agencies to develop the agenda first, present it to the different groups, and incorporate these groups in already established frameworks. Complex social dynamics, such as trust building and power relations, have often been underestimated and the view of social relationships simplified. Once a problem needing collaboration moves into the public arena, stakeholders tend to become frozen in polarized positions, and any real negotiation becomes difficult (58). Consequently, many attempts for ecosystem stewardship have failed.

In this review, we have explored the social dimension of adaptive comanagement of ecosystems and landscapes, referred to as systems of adaptive governance. The focus has been on social features and sources that seem to be of significance in responding to crisis, shaping change and building resilience for reorganization and renewal of social-ecological systems, both internally and in relation to external perturbations. This challenge involves linking a broad range of actors at multiple scales to deal with the interrelated dynamics of resources and ecosystems, management systems and social systems, as well as uncertainty, unpredictability, and surprise.

Adaptive governance focuses on experimentation and learning, and it brings together research on institutions and organizations for collaboration, collective

action, and conflict resolution in relation to natural resource and ecosystem management. The essential role of individuals needs to be recognized in this context (e.g., leadership, trust building, vision, and meaning); their social relations (e.g., actor groups, knowledge systems, social memory) and social networks serve as the web that tie together the adaptive governance system. It has cross-level and cross-scale activities and includes governmental policies that frame creativity. The notion of adaptation implies capacity to respond to change and even transform social-ecological systems into improved states.

Research on adaptive governance of social-ecological systems illustrate that the management of ecosystem and landscapes is complex to apprehend and implement and, therefore, cannot easily be subject to planning and control by a central organization, such as a national government. However, the conditions creating the opportunities for adaptive comanagement to self-organize, such as enabling legislation, flexible institutions, and recognition of bridging organization, are good candidates for governmental actions, which can be carefully tested and evaluated.

The review highlights the following four interacting aspects of importance in adaptive governance of complex social-ecological systems:

- Build knowledge and understanding of resource and ecosystem dynamics; detecting and responding to environmental feedback in a fashion that contributes to resilience require ecological knowledge and understanding of ecosystem processes and functions. All sources of understanding need to be mobilized, and management of complex adaptive systems may benefit from the combination of different knowledge systems. Social incentives for ecological knowledge generation need to be in place as well as the capacity to monitor and translate signals (feedback) from ecosystem dynamics into knowledge that can be used in the social system.
- Feed ecological knowledge into adaptive management practices; successful management is characterized by continuous testing, monitoring, and reevaluation to enhance adaptive responses, acknowledging the inherent uncertainty in complex systems. It is increasingly proposed that knowledge generation of ecosystem dynamics should be explicitly integrated with adaptive management practices rather than striving for optimization based on past records. This aspect emphasizes a learning environment that requires leadership and changes of social norms within management organizations.
- Support flexible institutions and multilevel governance systems; the adaptive governance framework is operationalized through adaptive comanagement whereby the dynamic learning characteristic of adaptive management is combined with the multilevel linkage characteristic of comanagement. The sharing of management power and responsibility may involve multiple and often polycentric institutional and organizational linkages among user groups or communities, government agencies, and nongovernmental organizations, i.e., neither centralization nor decentralization but cross-level interactions. Adaptive comanagement relies on the collaboration of a diverse set of

stakeholders, operating at different levels through social networks. This aspect emphasizes the role of multilevel social networks to generate and transfer knowledge and develop social capital as well as legal, political, and financial support to ecosystem management initiatives.

- Deal with external perturbations, uncertainty and surprise; it is not sufficient for a well-functioning multilevel governance system to be in tune with the dynamics of the ecosystems under management. It also needs to develop capacity for dealing with changes in climate, disease outbreaks, hurricanes, global market demands, subsidies, and governmental policies. The challenge for the social-ecological system is to accept uncertainty, be prepared for change and surprise, and enhance the adaptive capacity to deal with disturbance. Nonresilient social-ecological systems are vulnerable to external change, whereas a resilient system may even make use of disturbances as opportunities to transform into more desired states.

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